(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 620 622 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.03.2020 Bulletin 2020/11

(51) Int Cl.:
F01L 1/18 *(2006.01)* ***F01L 13/00*** *(2006.01)*

(21) Application number: **19195185.4**

(22) Date of filing: **03.09.2019**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **05.09.2018 US 201816122194**

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(54) ROCKER ARM

(57) A rocker arm (10) includes an outer arm (14) with an outer follower including a first outer roller (30a) and a second outer roller (30b) both supported on an outer arm roller shaft (54), the outer arm roller shaft (54) having a first portion having a first diameter (54d) which is supported in the outer arm (14) by a first outer bearing (60a); a second portion having a second diameter (54e) which is supported in the outer arm (14) by a second outer bearing (60b); and a third portion having a third diameter (54d) such that the third diameter (54d) is smaller than the first diameter (54d) and the second diameter (54e). An inner arm (12) selectively pivots relative to the outer arm (14), the inner arm (12) having an inner follower (20) and also having an inner arm aperture (12c) through which the outer arm roller shaft (54) extends such that the third portion of the outer arm roller shaft (54) is located within the inner arm aperture (12c).

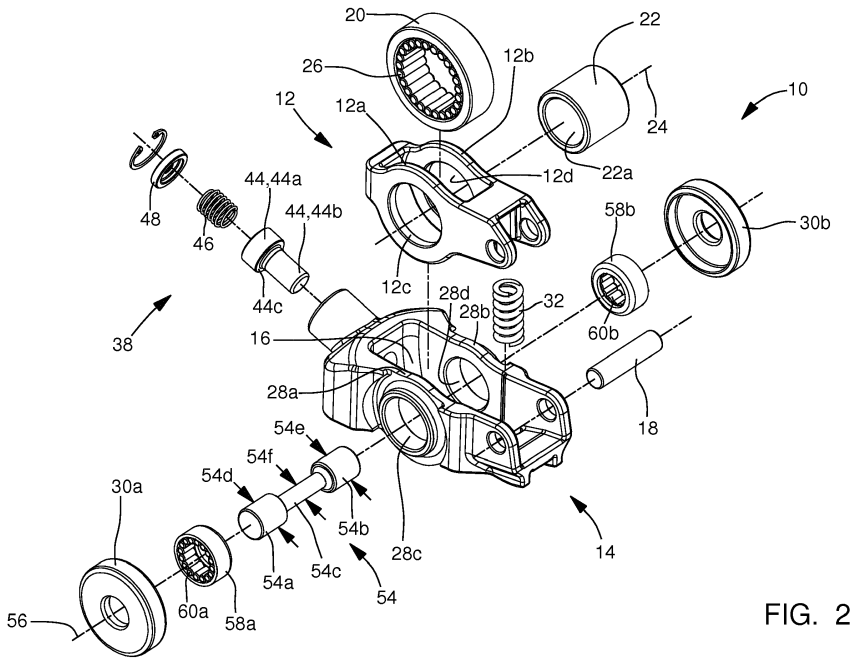


FIG. 2

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Description

TECHNICAL FIELD OF INVENTION

[0001] The present invention relates to a rocker arm for valve train of an internal combustion engine; more particularly to a rocker arm with an inner arm which selectively pivots relative to an outer arm; and even more particularly to such a rocker arm where the outer arm includes a pair of rollers supported on a roller shaft which extends through an aperture of the inner arm.

BACKGROUND OF INVENTION

[0002] Variable valve activation mechanisms for internal combustion engines are well known. It is known to lower the lift, or even to provide no lift at all, of one or more valves of an internal combustion engine, during periods of light engine load. Such valve deactivation or valve lift switching can substantially improve fuel efficiency.

[0003] A rocker arm acts between a rotating eccentric camshaft lobe and a pivot point on the internal combustion engine, such as a hydraulic lash adjuster, to open and close an engine valve. Switchable rocker arms may be a "deactivation" type or a "two-step" type. The term switchable deactivation rocker arm, as used herein, means the switchable rocker arm is capable of switching from a valve lift mode to a no lift mode. The term switchable two-step rocker arm, as used herein, means the switchable rocker arm is capable of switching from a first valve lift mode to a second and lesser valve lift mode, that is greater than no lift. It should be noted that the second valve lift mode may provide one or both of decreased lift magnitude and decreased lift duration of the engine valve compared to the first valve lift mode. When the term "switchable rocker arm" is used herein, by itself, it includes both types.

[0004] A typical switchable rocker arm includes an outer arm and an inner arm where the inner arm includes an inner arm follower which follows a first profile of a camshaft of the internal combustion engine and where the outer arm includes a pair of outer arm followers which follow respective second and third profiles of the camshaft. The follower of the inner arm and the followers of the outer arm may be either sliding surfaces or rollers and combinations thereof. The inner arm is movably connected to the outer arm and can be switched from a coupled state wherein the inner arm is immobilized relative to the outer arm, to a decoupled state wherein the inner arm can move relative to the outer arm. Typically, the outer arm of the switchable rocker arm is pivotally supported at a first end by the hydraulic lash adjuster which fits into a socket of the outer arm. A second end of the outer arm operates against an associated engine valve for opening and closing the valve by the rotation of an associated eccentric cam lobe acting on the follower of the inner arm. The inner arm is connected to the outer arm for pivotal movement about the outer arm's second end with the follower of the inner arm disposed between the first and second ends of the outer arm. Switching between the coupled state and the decoupled state is accomplished through a lock pin which is slidingly positioned in a lock pin bore of the outer arm. One end of the lock pin is moved into and out of engagement with the inner arm. Consequently, when the lock pin is engaged with the inner arm, the coupled state is achieved. Conversely, when the lock pin is not engaged with the inner arm, the decoupled state is achieved. As shown in United States Patent No. 7,305,951 to Fernandez et al., the disclosure of which is hereby incorporated by reference in its entirety, the other end of the lock pin acts as a piston upon which pressurized oil is applied and vented to affect the position of the lock pin. Also as shown by Fernandez et al., oil is supplied to the lock pin via an oil supply bore which originates in the socket and breaks into the lock pin bore.

[0005] It is sometimes desirable for each of the inner arm follower and outer arm followers to be rollers which rotate when engaged with the camshaft in order to minimize friction; various embodiments of which are illustrated in United States Patent No. 6,532,920 to Sweetnam et al. In one implementation shown in FIG. 12 of Sweetnam et al., the outer arm rollers are supported on a common roller shaft which extends through an aperture of the inner arm and through an aperture of an inner arm roller shaft which supports the inner arm roller. However, this implementation suffers from travel of the inner arm being limited by the clearance provided between the outer arm roller shaft and the aperture of the inner arm roller shaft and the roller shaft must be sufficiently large to support the bearing loads. In another implementation disclosed in United States Patent No. 6,976,461 to Rorig et al., and in particular FIG. 3, the outer rollers may be separately supported on individual outer roller shafts, thereby omitting the need for a shaft to extend through the inner arm which would limit travel of the inner arm relative to the outer arm. However, this implementation suffers from increased packaging size of the rocker arm due to the outer rollers each being supported on both lateral sides thereof.

[0006] What is needed is a rocker arm which minimizes or eliminates one or more of the shortcomings as set forth above.

SUMMARY OF THE INVENTION

[0007] Briefly described, a rocker arm is provided for transmitting rotational motion from a camshaft to opening and closing motion of a combustion valve in an internal combustion engine. The rocker arm includes an outer arm with an outer follower comprising a first outer roller and a second outer roller both supported on an outer arm roller shaft which is centered about, and extends along, an outer arm roller shaft axis about which the first outer roller and the second outer roller rotate, the outer arm roller shaft having 1) an outer arm roller shaft first portion

having a first diameter which is supported in the outer arm by a first outer bearing; 2) an outer arm roller shaft second portion having a second diameter which is supported in the outer arm by a second outer bearing; and 3) an outer arm roller shaft third portion having a third diameter such that the third diameter is smaller than the first diameter and is also smaller than the second diameter; an inner arm which selectively pivots relative to the outer arm, the inner arm having an inner follower and also having an inner arm aperture through which the outer arm roller shaft extends such that the outer arm roller shaft third portion is located within the inner arm aperture; a lost motion spring which biases the inner arm to pivot relative to the outer arm in a first direction; and a lock pin which moves between 1) a coupled position in which the lock pin prevents the inner arm from pivoting relative to the outer arm past a predetermined position of the inner arm relative to the outer arm in a second direction which is opposite of the first direction and 2) a decoupled position in which the lock pin permits the inner arm to pivot relative to the outer arm past the predetermined position in the second direction.

[0008] The inner follower of the rocker arm may comprise an inner roller which is supported on an inner arm roller shaft which may be centered about, and extend along an inner arm roller shaft axis about which the inner roller rotates, the inner roller being supported on the inner arm roller shaft by an inner bearing located radially between the inner roller and the inner arm roller shaft, the inner arm roller shaft having an inner arm roller shaft aperture extending therethrough within which the outer arm roller shaft third portion is located.

[0009] The outer arm roller shaft first portion of the rocker arm and the outer arm roller shaft second portion may not be disposed within the inner arm roller shaft aperture.

[0010] The rocker arm's outer arm roller shaft first portion and the outer arm roller shaft second portion may not be disposed within the inner arm aperture.

[0011] The rocker arm's outer arm roller shaft third portion may be located axially between the outer arm roller shaft first portion and the outer arm roller shaft second portion.

[0012] The rocker arm's outer arm roller shaft third portion may connect the outer arm roller shaft first portion to the outer arm roller shaft second portion.

[0013] The rocker arm for transmitting rotational motion from a camshaft to opening and closing motion of a combustion valve in an internal combustion engine may comprise:

an outer arm with an outer follower comprising a first outer roller and a second outer roller both supported on an outer arm roller shaft which is centered about, and extends along, an outer arm roller shaft axis about which the first outer roller and the second outer roller rotate, the outer arm roller shaft having 1) an outer arm roller shaft first portion having a first diameter which is supported in the outer arm; 2) an outer arm roller shaft second portion having a second diameter which is supported in the outer arm; and 3) an outer arm roller shaft third portion having a third diameter such that the third diameter is smaller than the first diameter and is also smaller than the second diameter;

an inner arm which selectively moves relative to the outer arm, the inner arm having an inner arm aperture through which the outer arm roller shaft extends such that the outer arm roller shaft third portion is located within the inner arm aperture;

a lost motion spring which biases the inner arm to move relative to the outer arm in a first direction; and

a lock pin which moves between 1) a coupled position in which the lock pin prevents the inner arm from moving relative to the outer arm past a predetermined position of the inner arm relative to the outer arm in a second direction which is opposite of the first direction and 2) a decoupled position in which the lock pin permits the inner arm to move relative to the outer arm past the predetermined position in the second direction.

[0014] Within the rocker arm the inner arm may include an inner follower which may comprise an inner roller which is supported on an inner arm roller shaft which is centered about, and extends along an inner arm roller shaft axis about which the inner roller rotates, the inner arm roller shaft having an inner arm roller shaft aperture extending therethrough within which the outer arm roller shaft third portion is located.

[0015] The outer arm roller shaft first portion of the rocker arm and the outer arm roller shaft second portion may not be disposed within the inner arm roller shaft aperture.

[0016] The outer arm roller shaft first portion and the outer arm roller shaft second portion may not be disposed within the inner arm aperture.

[0017] Within the rocker arm the outer arm roller shaft third portion may be located axially between the outer arm roller shaft first portion and the outer arm roller shaft second portion.

[0018] The outer arm roller shaft third portion within te rocker arm may connect the outer arm roller shaft first portion to the outer arm roller shaft second portion (54b).

[0019] The rocker arm with outer arm roller shaft as described herein allows for increased travel of the inner arm relative to the outer arm without increasing the packaging size of the rocker arm and without diminishing the load capacity of the outer arm bearings.

BRIEF DESCRIPTION OF DRAWINGS

[0020] This invention will be further described with reference to the accompanying drawings in which:

FIG. 1 is an isometric view of a rocker arm in accord-

ance with the present invention;

FIG. 2 is an exploded isometric view of the rocker arm of FIG. 1;

FIG. 3 is a cross-sectional view of the rocker arm of FIG. 1, taken through a plane that is perpendicular to an axis of rotation of a central follower of the rocker arm, showing a latching arrangement of the rocker arm in a decoupled state;

FIG. 4 is the cross-sectional view of FIG. 3, now showing the latching arrangement in a coupled state; and

FIG. 5 is a cross-sectional view of the rocker arm of FIG. 1, taken through a plane that is parallel to an axis of rotation of the outer followers of the rocker arm.

DETAILED DESCRIPTION OF INVENTION

[0021] Referring to the figures, a rocker arm 10 in accordance with the invention is illustrated where rocker arm 10 is either a two-step rocker arm or a deactivation rocker arm, which may generically be referred to as a switchable rocker arm. Rocker arm 10 is included in valve train (not shown) of an internal combustion engine (not shown) in order to translate rotational motion of a camshaft (not shown) to reciprocating motion of a combustion valve (not shown). Rocker arm 10 includes an inner arm 12 that is pivotably disposed in a central opening 16 in an outer arm 14. Inner arm 12 selectively pivots within outer arm 14 about a pivot shaft 18. Inner arm 12 includes an inner follower illustrated as an inner roller 20 carried by an inner arm roller shaft 22 that is supported by inner arm 12 such that inner roller 20 and inner arm roller shaft 22 are centered about an inner arm roller shaft axis 24. Inner roller 20 is configured to follow the camshaft in order to selectively impart lifting motion on a respective combustion valve. An inner bearing 26 rotatably supports inner roller 20 on inner arm roller shaft 22. Inner bearing 26 may be, for example, a plurality of rollers or needle bearings as shown. Inner arm roller shaft 22 is fixed to inner arm 12, by way of non-limiting example only, by staking each end of inner arm roller shaft 22 in order to cause each end of inner arm roller shaft 22 to be increased in diameter to prevent removal from inner arm 12. In an alternative, inner arm roller shaft 22 may be left to float axially, i.e. along inner arm roller shaft axis 24, while being constrained within central opening 16 by opposing sides of outer arm 14. Outer arm 14 includes an outer arm wall 28a and an outer arm wall 28b positioned parallel to each other such that outer arm wall 28a and outer arm wall 28b are perpendicular to inner arm roller shaft axis 24 and such that outer arm wall 28a and outer arm wall 28b are spaced apart from each other to define central opening 16 therebetween. Outer arm 14 also includes outer followers, illustrated as outer roller 30a and outer roller 30b, such that outer roller 30a is located adjacent to outer arm wall 28a outside of central opening 16 and such that outer roller 30b is located adjacent to outer arm wall 28b outside of central opening 16. Outer roller 30a and outer roller 30b are configured to follow respective lobes (not shown) of the camshaft, for example low-lift lobes which impart lifting motion on a respective combustion valve or null lobes which do not impart lifting motion on a respective combustion valve. A lost motion spring 32 acts between inner arm 12 and outer arm 14 to pivot inner arm 12 away from outer arm 14 in a first direction illustrated as clockwise in FIGS. 3 and 4. A socket 34 for pivotably mounting rocker arm 10 on a lash adjuster (not shown) is included at a first end 14a of outer arm 14 while a pad 36 for actuating a valve stem (not shown) is proximal to a second end 14b of outer arm 14. A latching arrangement 38 disposed within outer arm 14 at first end 14a thereof selectively permits inner arm 12 to pivot relative to outer arm 14 about pivot shaft 18 and also selectively prevents inner arm 12 from pivoting relative to outer arm 14 about pivot shaft 18. While the follower of inner arm 12 has been illustrated as inner roller 20, it should be understood that the follower of inner arm 12 may alternatively be a sliding surface as shown in United States Patent No. 7,305,951 to Fernandez et al.

[0022] Rocker arm 10 is selectively switched between a coupled state and a decoupled state by latching arrangement 38 which is actuated by application and venting of pressurized oil as will be described in greater detail later. In the coupled state as shown in FIG. 4, inner arm 12 is prevented from pivoting relative to outer arm 14 past a predetermined position of inner arm 12 relative to outer arm 14 in a second direction, shown as counterclockwise in FIG. 4 which is opposite in direction to the first direction. In this way, in the coupled state, inner arm 12, and therefore inner arm roller shaft 22, is coupled to outer arm 14, and rotation of the camshaft is transferred from inner roller 20 through inner arm roller shaft 22 to pivotal movement of outer arm 14 about the lash adjuster which, in turn, reciprocates the associated valve. In the decoupled state as shown in FIG. 3, inner arm 12 is able to pivot relative to outer arm 14 past the predetermined position in the second direction. In this way, in the decoupled state, inner arm 12, and therefore inner arm roller shaft 22, is decoupled from outer arm 14. Thus, inner arm roller shaft 22 does not transfer rotation of the camshaft to pivotal movement of outer arm 14, and the associated valve is not reciprocated. Rather, inner arm 12 together with inner roller 20 and inner arm roller shaft 22 reciprocate within central opening 16, thereby compressing and uncompressing lost motion spring 32 in a cyclic manner such that lost motion spring 32 biases inner arm 12 to pivot relative to outer arm 14 in the first direction, shown as clockwise in FIG. 3.

[0023] Latching arrangement 38 will now be described in greater detail. Latching arrangement 38 includes a lock pin bore 40 which is centered about, and extends along,

a lock pin bore axis 42 into outer arm 14. Latching arrangement 38 also includes a lock pin 44 which is slidably disposed in lock pin bore 40. Lock pin 44 selectively engages inner arm 12, thereby preventing inner arm 12 from pivoting relative to outer arm 14 in the second direction past the predetermined position. Lock pin 44 also selectively disengages inner arm 12, thereby allowing inner arm 12 to pivot relative to outer arm 14 in the second direction past the predetermined position. Latching arrangement 38 also includes a lock pin spring 46 which urges lock pin 44 into engagement with inner arm 12 when desired. Lock pin spring 46 is grounded to outer arm 14 by a lock pin stop 48 which is fixed within lock pin bore 40, for example only, by interference fit and/or a retaining ring. Lock pin spring 46 is captured axially between lock pin stop 48 and lock pin 44. Conversely, pressurized oil is supplied to lock pin 44 through a rocker arm oil passage 50 which extends from socket 34 to lock pin bore 40, thereby compressing lock pin spring 46 and disengaging lock pin 44 from inner arm 12 when desired. The supply of pressurized oil to lock pin 44 may be controlled, for example, by an oil control valve (not shown) which receives oil from an oil supply (not shown) of the internal combustion engine.

[0024] Lock pin bore 40 includes three distinct sections, namely a lock pin bore first section 40a that is distal from inner arm 12, a lock pin bore second section 40b that is proximal to inner arm 12, and a lock pin bore third section 40c that is coaxial with, and axially between, lock pin bore first section 40a and lock pin bore second section 40b. Lock pin bore first section 40a is larger in diameter than lock pin bore third section 40c, thereby defining a lock pin bore shoulder 40d where lock pin bore first section 40a meets lock pin bore third section 40c such that lock pin bore shoulder 40d limits the extent to which lock pin 44 is able to travel toward inner arm 12. As shown, lock pin bore first section 40a may itself comprise multiple discrete diameters. Lock pin bore second section 40b is smaller in diameter than both lock pin bore first section 40a and lock pin bore third section 40c.

[0025] Lock pin 44 is defined by two distinct sections, namely a lock pin piston section 44a which is disposed within lock pin bore first section 40a and a lock pin locking section 44b which is disposed within lock pin bore second section 40b and lock pin bore third section 40c under all operating conditions and is also disposed within lock pin bore first section 40a when lock pin 44 is not engaged with inner arm 12. Lock pin piston section 44a is sized to fit within lock pin bore first section 40a in a close sliding fit such that oil is substantially prevented from passing between the interface of lock pin piston section 44a and lock pin bore first section 40a, radial movement of lock pin piston section 44a within lock pin bore first section 40a is substantially prevented, and lock pin piston section 44a is allowed to move along lock pin bore axis 42 within lock pin bore first section 40a substantially uninhibited. Lock pin locking section 44b is sized to fit within lock pin bore second section 40b in a close sliding fit such that oil is substantially prevented from passing between the interface of lock pin locking section 44b and lock pin bore second section 40b, radial movement of lock pin locking section 44b is substantially prevented, and lock pin locking section 44b is allowed to move along lock pin bore axis 42 within lock pin bore second section 40b substantially uninhibited. Consequently, a lock pin shoulder 44c is defined between lock pin piston section 44a and lock pin locking section 44b, thereby providing a surface for oil to act upon and also providing a surface to abut lock pin bore shoulder 40d to limit travel of lock pin 44 toward inner arm 12. Conversely, the travel of lock pin 44 away from inner arm 12 is limited by lock pin stop 48. Since lock pin bore third section 40c is larger in diameter than lock pin bore second section 40b, an annular pressure chamber 52 is defined radially between lock pin locking section 44b and lock pin bore third section 40c. Rocker arm oil passage 50 enters lock pin bore 40 at lock pin bore third section 40c such that rocker arm oil passage 50 is located entirely between lock pin bore first section 40a and lock pin bore second section 40b in order for the oil to be supplied to pressure chamber 52 and have access to lock pin shoulder 44c.

[0026] While latching arrangement 38 has been illustrated herein as defaulting to the coupled position in the absence of hydraulic pressure, it should now be understood that latching arrangement 38 may alternatively be configured to default to the decoupled position in the absence of hydraulic pressure. This may be accomplished, for example, by reversing the direction which lock pin spring 46 acts upon lock pin 44. Furthermore, while latching arrangement 38 has been illustrated as being actuated based upon hydraulic pressure, other forms of actuation are anticipated, for example, by including a solenoid actuator which affects the position of lock pin 44 based on application of an electric current to the solenoid actuator.

[0027] Inner arm 12 together with inner roller 20 and inner arm roller shaft 22 will now be described in greater detail. Inner arm 12 includes an inner arm wall 12a and an inner arm wall 12b which are parallel to each other such that inner roller 20 is located between inner arm wall 12a and inner arm wall 12b. Inner arm wall 12a includes an inner arm aperture 12c extending therethrough such that inner arm aperture 12c is centered about, and extends along, inner arm roller shaft axis 24 and such that inner arm aperture 12c is cylindrical. Similarly, inner arm wall 12b includes an inner arm aperture 12d extending therethrough such that inner arm aperture 12d is centered about, and extends along, inner arm roller shaft axis 24 and such that inner arm aperture 12d is cylindrical. Inner arm roller shaft 22 is received within, and fixed within, inner arm aperture 12c and inner arm aperture 12d. Inner arm roller shaft 22 may be fixed within inner arm aperture 12c and inner arm aperture 12d, for example, by deforming the axial ends of inner arm roller shaft 22, i.e. by staking or riveting; welding; interference fit; or combinations thereof. Inner bearing 26, illustrated herein

by way of non-limiting example as a plurality of rollers, is located radially between the outer periphery of inner arm roller shaft 22 and the inner periphery of inner roller 20. In this way, inner roller 20 is able to freely rotate about inner arm roller shaft axis 24 in use. Inner arm roller shaft 22 includes an inner arm roller shaft aperture 22a extending therethrough such that inner arm roller shaft aperture 22a is centered about, and extends along, inner arm roller shaft axis 24 and such that inner arm roller shaft aperture 22a connects the axial ends of inner arm roller shaft 22.

[0028] Outer arm 14 is provided with an outer arm roller shaft 54 on which both outer roller 30a and outer roller 30b are supported such that outer arm roller shaft 54 is centered about, and extends along, an outer arm roller shaft axis 56 which is parallel to inner arm roller shaft axis 24. Outer arm roller shaft 54 extends through inner arm roller shaft aperture 22a, and consequently, also extends through inner arm aperture 12c and inner arm aperture 12d. In order to support outer arm roller shaft 54 in outer arm 14, outer arm wall 28a is provided with an outer arm wall aperture 28c extending therethrough which is centered about outer arm roller shaft axis 56, and similarly, outer arm wall 28b is provided with an outer arm wall aperture 28d extending therethrough which is centered about outer arm roller shaft axis 56. Also in order to support outer arm roller shaft 54 in outer arm 14, an outer arm bearing race 58a is located within, and fixed within, outer arm wall aperture 28c, for example by interference fit, and similarly, an outer arm bearing race 58b is located within, and fixed within, outer arm wall aperture 28d, for example by interference fit. Also in order to support outer arm roller shaft 54 in outer arm 14, an outer bearing 60a is located radially between outer arm bearing race 58a and outer arm roller shaft 54, and similarly, an outer bearing 60b is located radially between outer arm bearing race 58b and outer arm roller shaft 54. As illustrated herein, outer bearing 60a and outer bearing 60b may be a plurality of rollers but may alternatively be a plurality of balls. In an alternative, not shown, outer bearing 60a and outer bearing 60b may ride directly in outer arm wall aperture 28c and outer arm wall aperture 28d respectively by omitting outer arm bearing race 58a and outer arm bearing race 58b.

[0029] Outer arm roller shaft 54 includes three distinct portions, namely an outer arm roller shaft first portion 54a which is supported by outer bearing 60a, an outer arm roller shaft second portion 54b which is supported by outer bearing 60b, and an outer arm roller shaft third portion 54c located between outer arm roller shaft first portion 54a and outer arm roller shaft second portion 54b. Outer arm roller shaft first portion 54a is centered about, and extends along, outer arm roller shaft axis 56 such that outer arm roller shaft first portion 54a is cylindrical with diameter 54d and is located within outer arm wall aperture 28c. Similarly, outer arm roller shaft second portion 54b is centered about, and extends along, outer arm roller shaft axis 56 such that outer arm roller shaft second portion 54b is cylindrical with diameter 54e and is located within outer arm wall aperture 28d. Diameter 54e is preferably equal to diameter 54d. Outer arm roller shaft third portion 54c is centered about, and extends along, outer arm roller shaft axis 56 such that outer arm roller shaft third portion 54c is cylindrical with diameter 54f where diameter 54f is smaller than diameter 54d and is also smaller than diameter 54e. Outer arm roller shaft third portion 54c is located within inner arm roller shaft aperture 22a, and consequently, outer arm roller shaft third portion 54c is located within inner arm aperture 12c and inner arm aperture 12d. It should be noted that neither of outer arm roller shaft first portion 54a and outer arm roller shaft second portion 54b are located within inner arm aperture 12c, inner arm aperture 12d, or inner arm roller shaft aperture 22a, and consequently the magnitude of travel of inner arm 12 pivoting relative to outer arm 14 can be as large as accommodated by the size of inner arm roller shaft aperture 22a and diameter 54f of outer arm roller shaft third portion 54c unless limited in some other way.

[0030] While inner arm roller shaft aperture 22a is illustrated in the figures as being cylindrical with a circular cross-sectional shape when sectioned perpendicular to inner arm roller shaft axis 24, it should be understood that inner arm roller shaft aperture 22a may alternatively be non-cylindrical with a cross-sectional shape that is other than circular. For example, the width, i.e. right to left as viewed in FIGS. 3 and 4, may be reduced while allowing the height, i.e. up and down as viewed in FIGS. 3 and 4, to remain the same in order to maintain the travel of inner arm 12 relative to outer arm 14 while increasing the strength of inner arm roller shaft 22.

[0031] Rocker arm 10 with outer arm roller shaft 54 as described herein allows for increased travel of inner arm 12 relative to outer arm 14 without increasing the packaging size of rocker arm 10 and without diminishing the load capacity of the outer bearing 60a and outer bearing 60b. More specifically, since diameter 54f of outer arm roller shaft third portion 54c is smaller than diameter 54d of outer arm roller shaft first portion 54a and diameter 54e of outer arm roller shaft second portion 54b, the clearance between inner arm roller shaft 22 and outer arm roller shaft 54 is increased, thereby increasing the travel permitted of inner arm 12 relative to outer arm 14. Furthermore, since diameter 54d of outer arm roller shaft first portion 54a and diameter 54e of outer arm roller shaft second portion 54b are larger than diameter 54f of outer arm roller shaft third portion 54c, the load capacity of outer bearing 60a and outer bearing 60b is increased compared to an arrangement were diameter 54d and diameter 54e would be reduced to match diameter 54f.

[0032] While this invention has been described in terms of preferred embodiments thereof, it is not intended to be so limited, but rather only to the extent set forth in the claims that follow.

Claims

1. A rocker arm (10) for transmitting rotational motion from a camshaft to opening and closing motion of a combustion valve in an internal combustion engine, said rocker arm (10) comprising:

   an outer arm (14) with an outer follower comprising a first outer roller (30a) and a second outer roller (30b) both supported on an outer arm roller shaft (54) which is centered about, and extends along, an outer arm roller shaft axis (56) about which said first outer roller (30a) and said second outer roller (30b) rotate, said outer arm roller shaft (54) having 1) an outer arm roller shaft first portion (54a) having a first diameter (54d) which is supported in said outer arm (14) by a first outer bearing (60a); 2) an outer arm roller shaft second portion (54b) having a second diameter (54e) which is supported in said outer arm (14) by a second outer bearing (60b); and 3) an outer arm roller shaft third portion (54c) having a third diameter (54d) such that said third diameter (54d) is smaller than said first diameter (54d) and is also smaller than said second diameter (54e);
   an inner arm (12) which selectively pivots relative to said outer arm (14), said inner arm (12) having an inner follower (20) and also having an inner arm aperture (12c) through which said outer arm roller shaft (54) extends such that said outer arm roller shaft third portion (54c) is located within said inner arm aperture (12c);
   a lost motion spring (32) which biases said inner arm (12) to pivot relative to said outer arm (14) in a first direction; and
   a lock pin (44) which moves between 1) a coupled position in which said lock pin (44) prevents said inner arm (12) from pivoting relative to said outer arm (14) past a predetermined position of said inner arm (12) relative to said outer arm (14) in a second direction which is opposite of said first direction and 2) a decoupled position in which said lock pin (44) permits said inner arm (12) to pivot relative to said outer arm (14) past said predetermined position in said second direction.

2. A rocker arm (10) as in claim 1, wherein said inner follower (20) comprises an inner roller (20) which is supported on an inner arm roller shaft (22) which is centered about, and extends along an inner arm roller shaft axis (24) about which said inner roller (20) rotates, said inner roller (20) being supported on said inner arm roller shaft (22) by an inner bearing (26) located radially between said inner roller (20) and said inner arm roller shaft (22), said inner arm roller shaft (22) having an inner arm roller shaft aperture (22a) extending therethrough within which said outer arm roller shaft third portion (54c) is located.

3. A rocker arm (10) as in claim 2, wherein said outer arm roller shaft first portion (54a) and said outer arm roller shaft second portion (54b) are not disposed within said inner arm roller shaft aperture (22a).

4. A rocker arm (10) as in claim 1, wherein said outer arm roller shaft first portion (54a) and said outer arm roller shaft second portion (54b) are not disposed within said inner arm aperture (12c).

5. A rocker arm (10) as in claim 1, wherein said outer arm roller shaft third portion (54c) is located axially between said outer arm roller shaft first portion (54a) and said outer arm roller shaft second portion (54b).

6. A rocker arm (10) as in claim 1, wherein said outer arm roller shaft third portion (54c) connects said outer arm roller shaft first portion (54a) to said outer arm roller shaft second portion (54b).

7. A rocker arm (10) for transmitting rotational motion from a camshaft to opening and closing motion of a combustion valve in an internal combustion engine, said rocker arm (10) comprising:

   an outer arm (14) with an outer follower comprising a first outer roller (30a) and a second outer roller (30b) both supported on an outer arm roller shaft (54) which is centered about, and extends along, an outer arm roller shaft axis (56) about which said first outer roller (30a) and said second outer roller (30b) rotate, said outer arm roller shaft (54) having 1) an outer arm roller shaft first portion (54a) having a first diameter (54d) which is supported in said outer arm (14); 2) an outer arm roller shaft second portion (54b) having a second diameter (54e) which is supported in said outer arm (14); and 3) an outer arm roller shaft third portion (54c) having a third diameter (54d) such that said third diameter (54d) is smaller than said first diameter (54d) and is also smaller than said second diameter (54e);
   an inner arm (12) which selectively moves relative to said outer arm (14), said inner arm (12) having an inner arm aperture (12c) through which said outer arm roller shaft (54) extends such that said outer arm roller shaft third portion (54c) is located within said inner arm aperture (12c);
   a lost motion spring (32) which biases said inner arm (12) to move relative to said outer arm (14) in a first direction; and
   a lock pin (44) which moves between 1) a coupled position in which said lock pin (44) prevents

said inner arm (12) from moving relative to said outer arm (14) past a predetermined position of said inner arm (12) relative to said outer arm (14) in a second direction which is opposite of said first direction and 2) a decoupled position in which said lock pin (44) permits said inner arm (12) to move relative to said outer arm (14) past said predetermined position in said second direction.

8. A rocker arm (10) as in claim 7, wherein said inner arm (12) includes an inner follower (20) which comprises an inner roller (20) which is supported on an inner arm roller shaft (22) which is centered about, and extends along an inner arm roller shaft axis (24) about which said inner roller (20) rotates, said inner arm roller shaft (22) having an inner arm roller shaft aperture (22a) extending therethrough within which said outer arm roller shaft third portion (54c) is located.

9. A rocker arm (10) as in claim 8, wherein said outer arm roller shaft first portion (54a) and said outer arm roller shaft second portion (54b) are not disposed within said inner arm roller shaft aperture (22a).

10. A rocker arm (10) as in claim 7, wherein said outer arm roller shaft first portion (54a) and said outer arm roller shaft second portion (54b) are not disposed within said inner arm aperture (12c).

11. A rocker arm (10) as in claim 7, wherein said outer arm roller shaft third portion (54c) is located axially between said outer arm roller shaft first portion (54a) and said outer arm roller shaft second portion (54b).

12. A rocker arm (10) as in claim 7, wherein said outer arm roller shaft third portion (54c) connects said outer arm roller shaft first portion (54a) to said outer arm roller shaft second portion (54b).

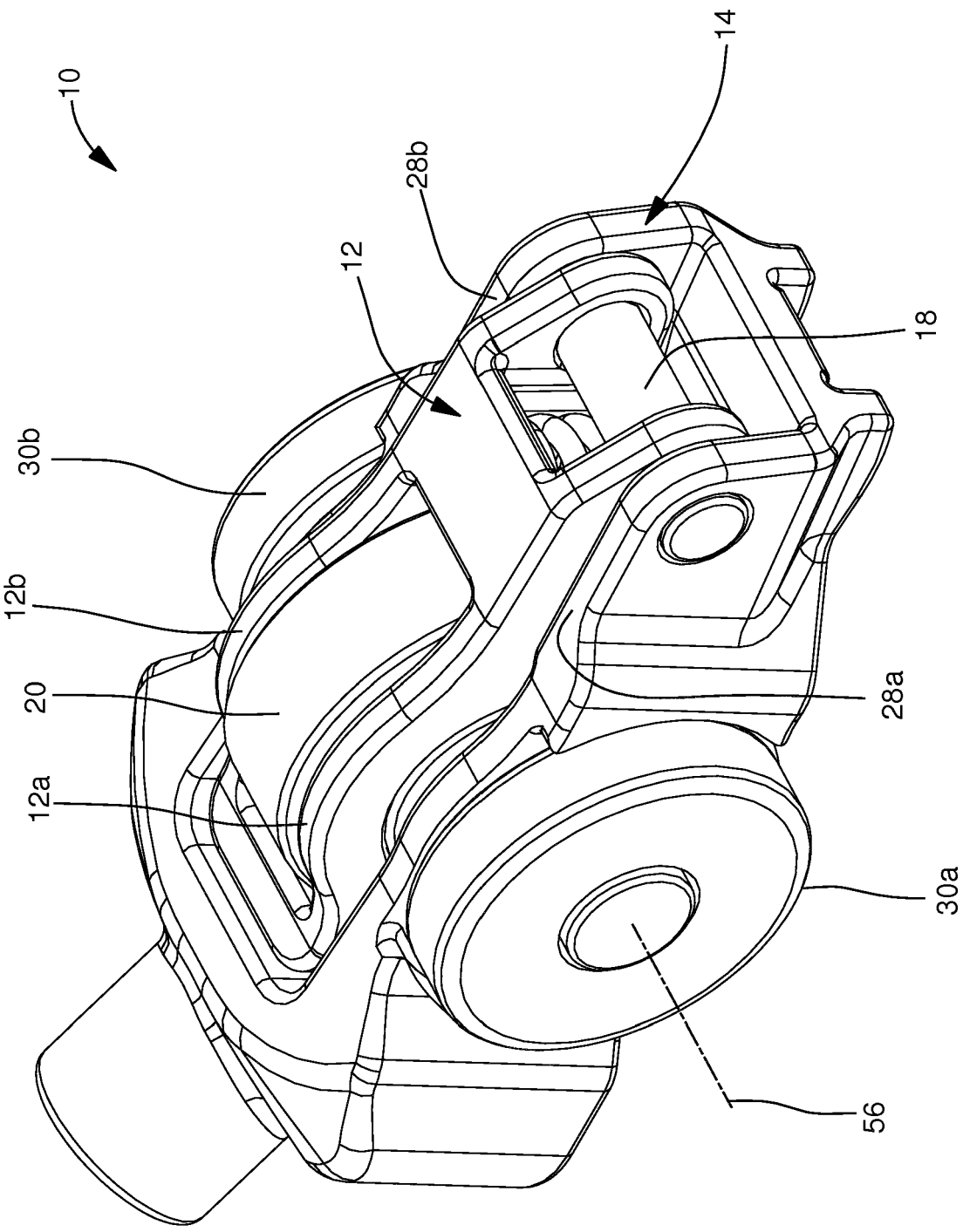


FIG. 1

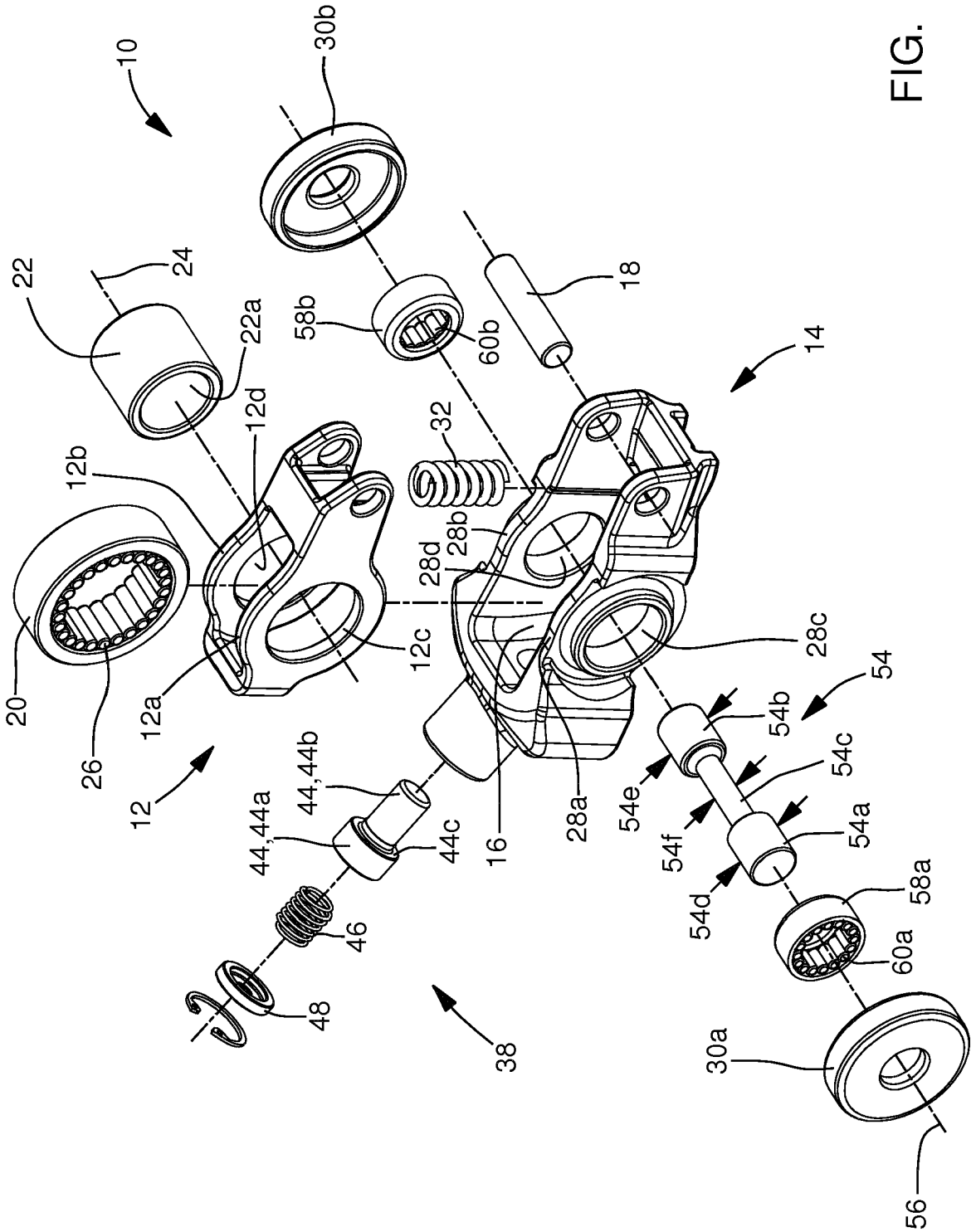

10
30b
22
24
22a
58b
60b
18
14
12d
32
12b
28b
28d
20
12c
28c
26
12a
54
54b
12
44,44b
54c
44,44a
54e
28a
44c
16
54f
54a
54d
58a
46
60a
48
38
30a
56

FIG. 2

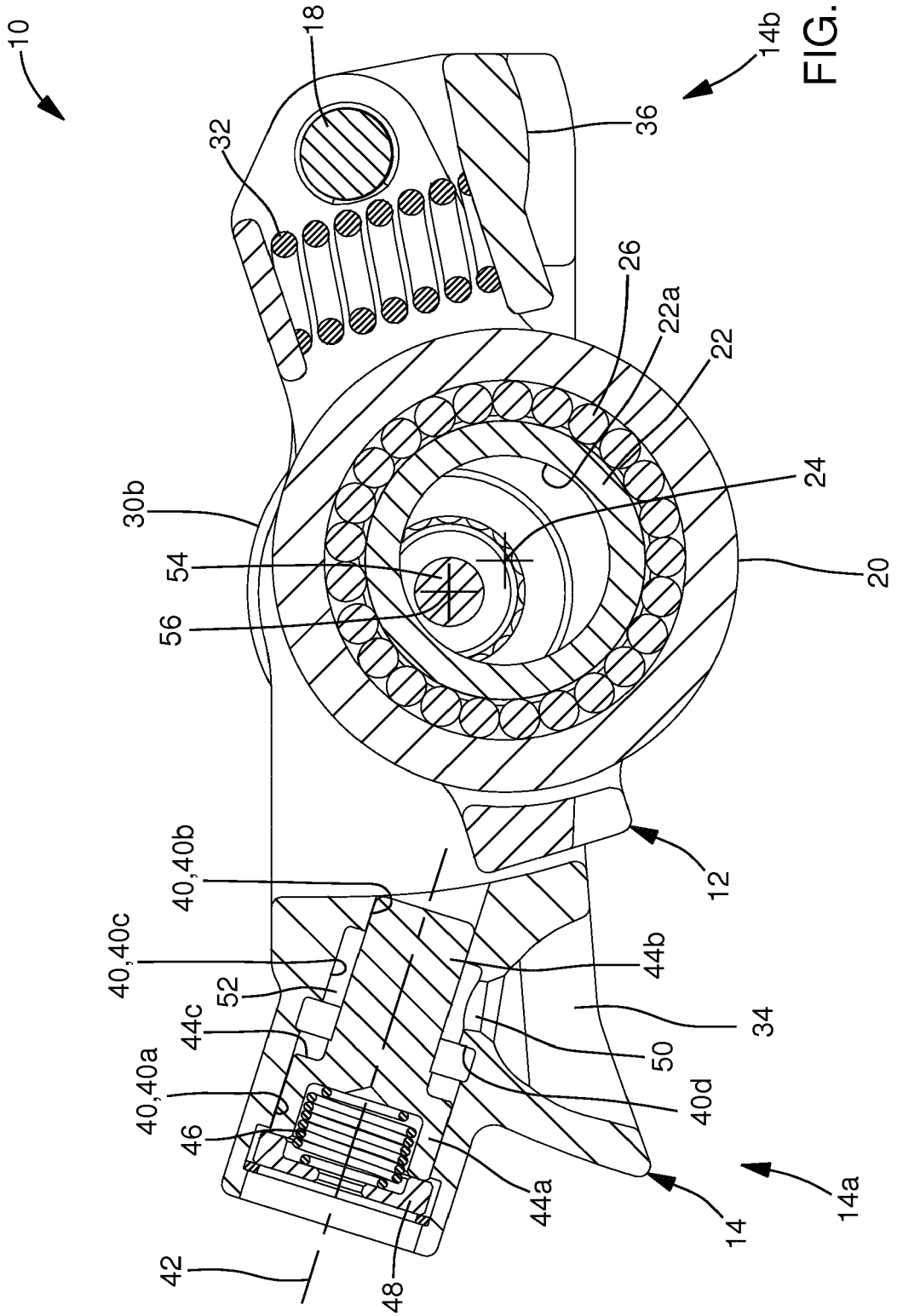

10
18
14b
32
36
26
22a
22
24
30b
54
56
20
12
40,40b
40,40c
52
44b
44c
34
50
40,40a
40d
46
44a
14
14a
42
48

FIG. 3

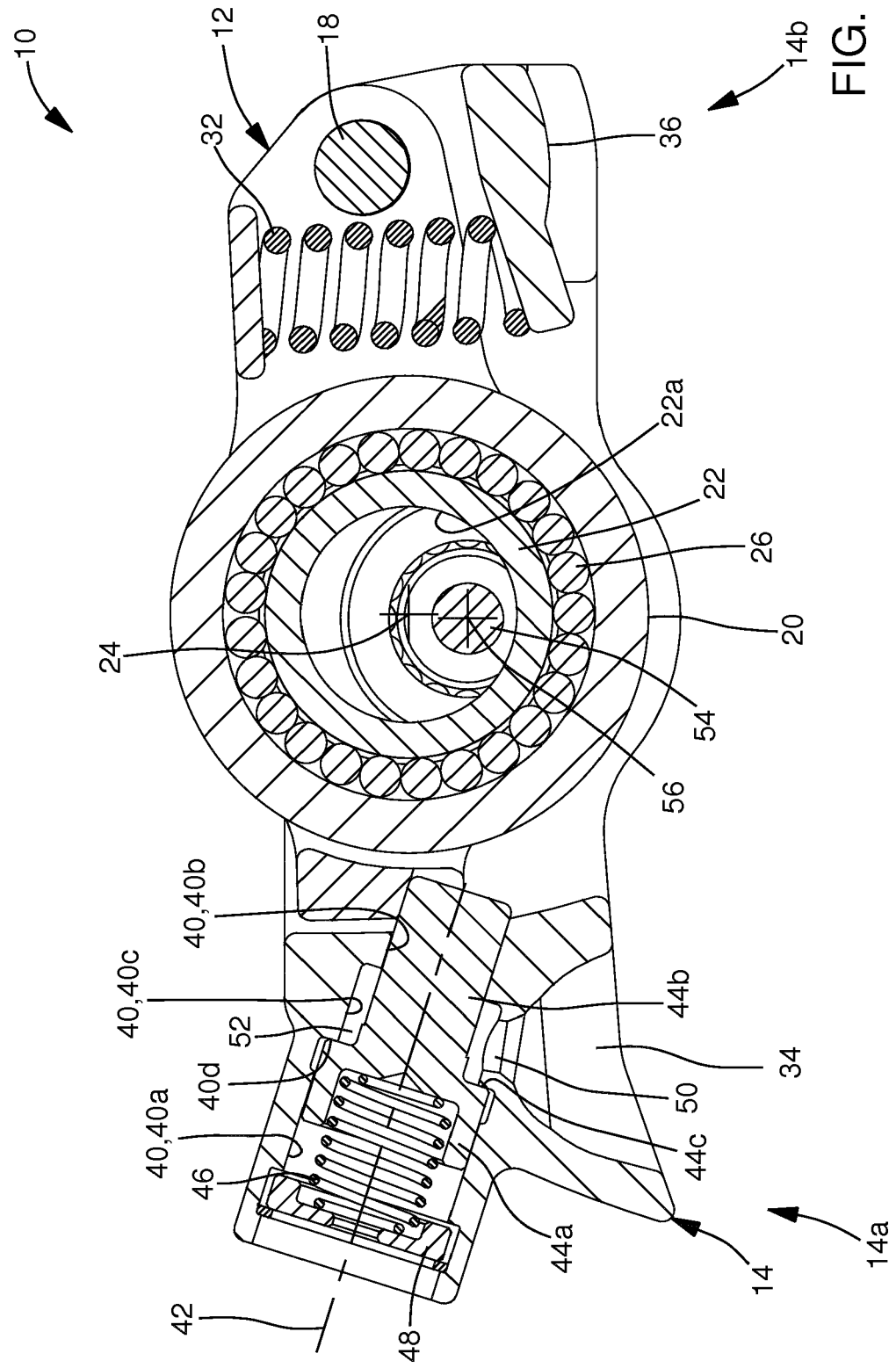

10
12
18
14b
32
36
22a
22
26
20
24
54
56
40,40b
40,40c
52
44b
34
40d
50
40,40a
44c
46
44a
14
14a
42
48

FIG. 4

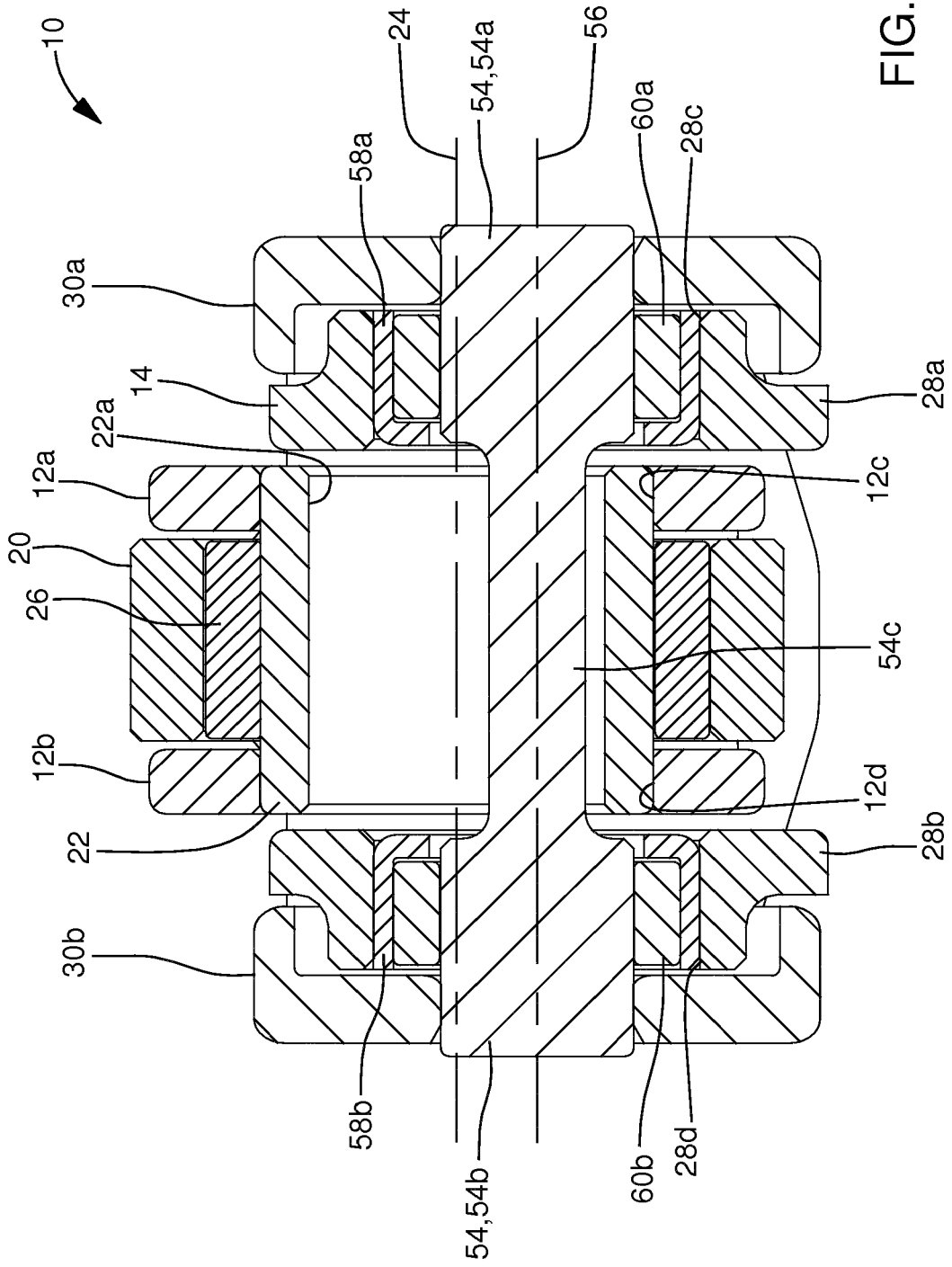

10
24
54,54a
56
58a
60a
28c
30a
14
22a
28a
12a
12c
20
26
54c
12b
12d
22
28b
30b
58b
60b
28d
54,54b

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 19 19 5185

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F01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	12 December 2019	Klinger, Thierry

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